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Title: Support Documentation for PIC Simulations on TWTs that Utilize High-e Dielectrics

Author(s): Krawczyk, Frank L.
Simakov, Evgenya Ivanovna

Intended for: Information exchange for collaboration with student at UNM ALbuquerque

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Support Documentation for PIC Simulations on TWTs that Utilize High- ϵ Dielectrics

Frank Krawczyk

Evgenya Simakov

November 08, 2017

Introduction

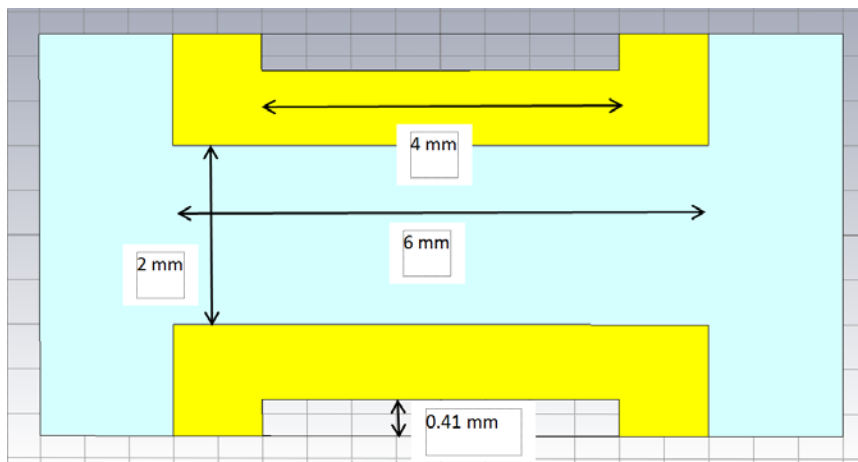
- **PIC simulations for a LANL LDRD project have shown issues with some of the results**
 - Numerical instabilities/noise
 - Prediction of synchronous energy
- **Benchmarking efforts have started**
 - Published NRL structure with similar characteristics was calculated and results were confirmed
 - Collaboration with the EE department at UNM in Albuquerque (Edl Shamiloglu) for calculation with another well benchmarked software package

Outline

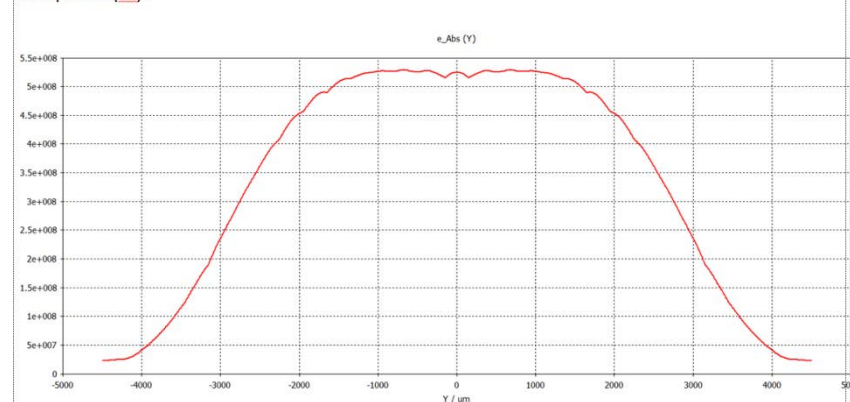
- **Basic RF structure and properties**
- **RF structure and RF coupler system**
- **PIC model w/o coupler**
- **Some PIC simulation results (CST-PS 2017)**
- **Questions**
- **Simulations of a simpler, circular TWT published by NRL**

Basic RF structure and properties

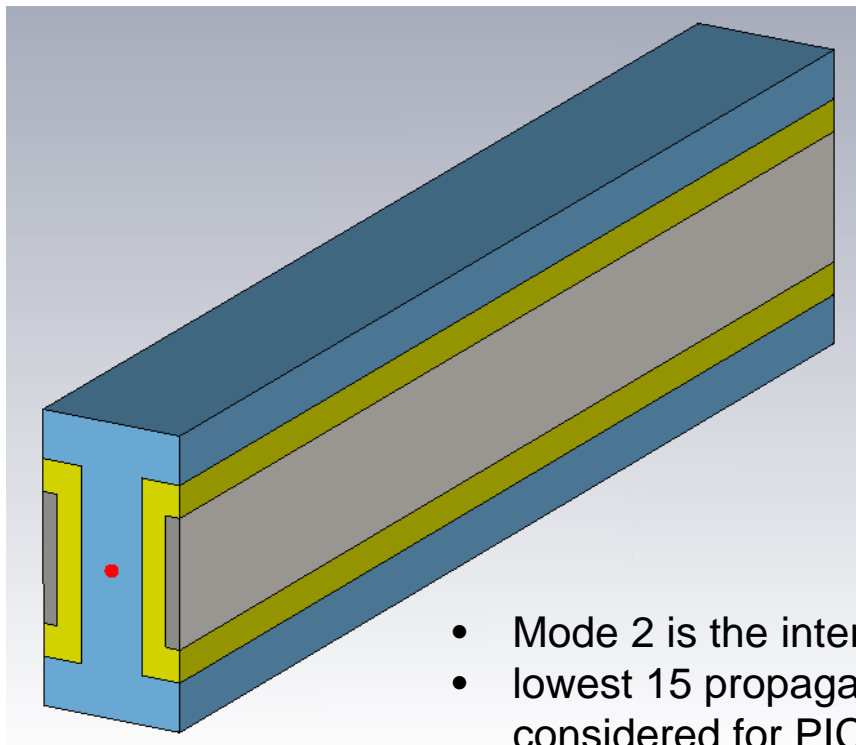
- Operation is at the center of Ka-band (33.25 GHz)
- One of the challenges of the structure is that the cross-section is highly over-moded
- Properties of the dielectric: $\epsilon_r=20$, $\tan \delta=0.001$
- Nominal velocity matches to 20 keV beam



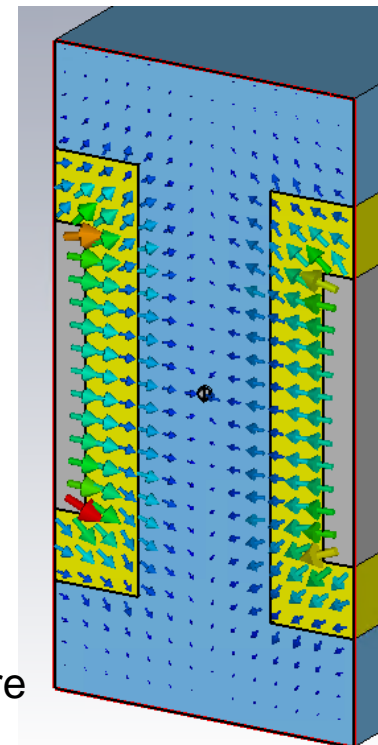
Field profile (E_z):



PIC model w/o coupler

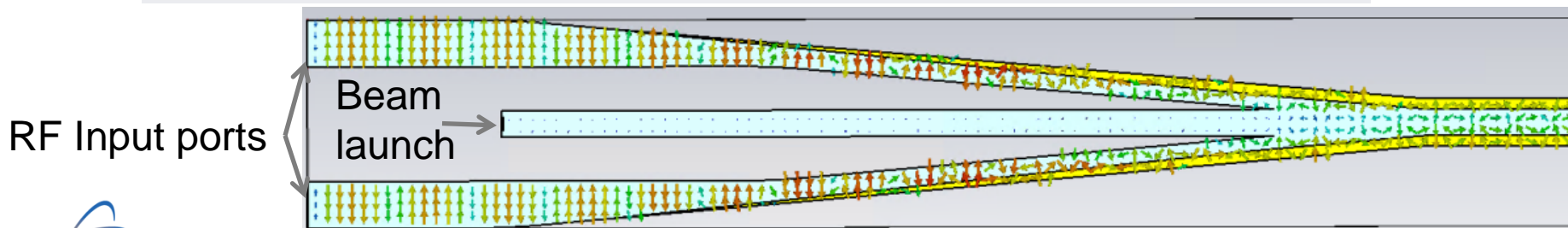
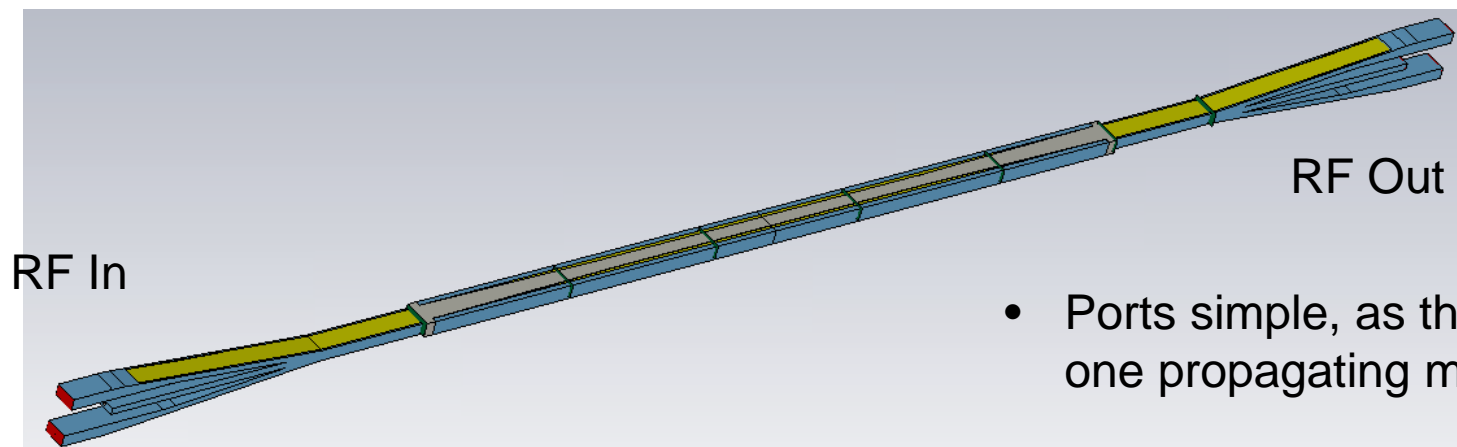


- Mode 2 is the interaction mode
- lowest 15 propagating modes are considered for PIC
- There are more than 100 propagating modes
- Sims use a mix of port modes and a Muir (damping) boundary



RF structure and RF coupler system

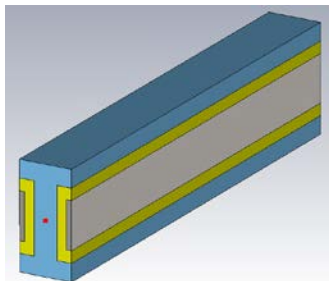
While this is not the final coupler/tube configuration – this one is more suitable for the PIC simulations. It has the proper mode generation from two empty ports that are 180 degrees out of phase.



Some PIC simulation results (CST-PS 2017)

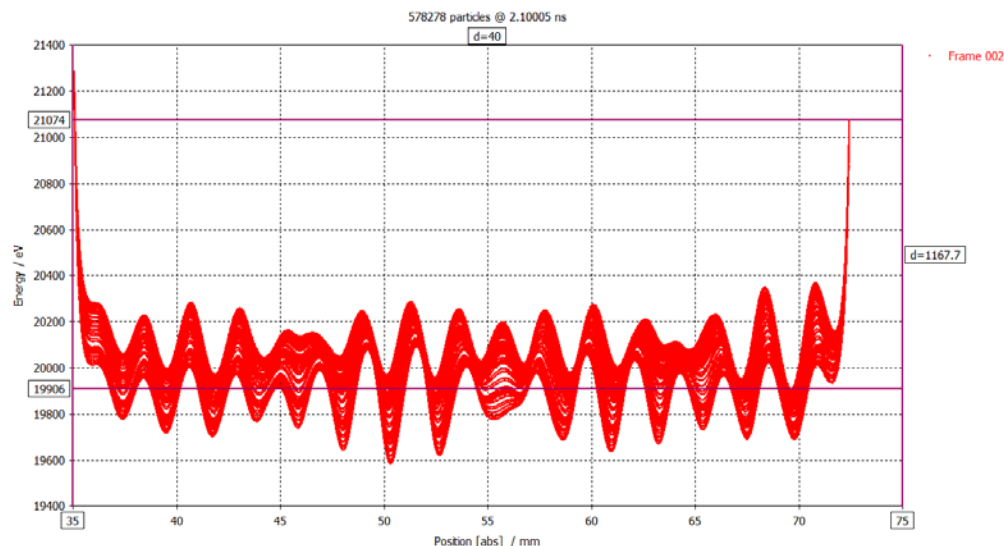
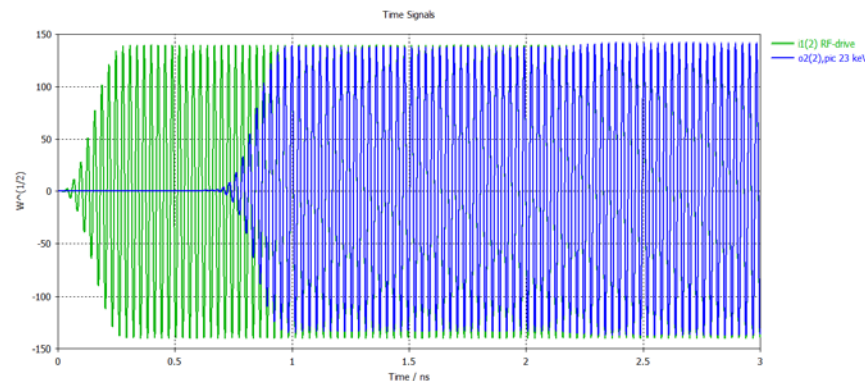
■ Simulations for the interaction structure alone show no gain

- RF input (green) and RF output show the same amplitude over a wide range of beam energies (20-25 keV)



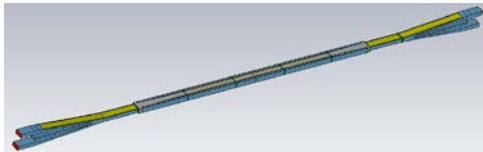
■ and unphysical potential depression (> 1 keV)

- Snapshot of energy along structure



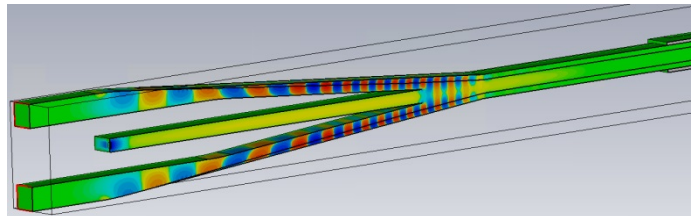
Some PIC simulation results (CST-PS 2017)

- Simulations for full structure show gain, but at much higher energy than expected

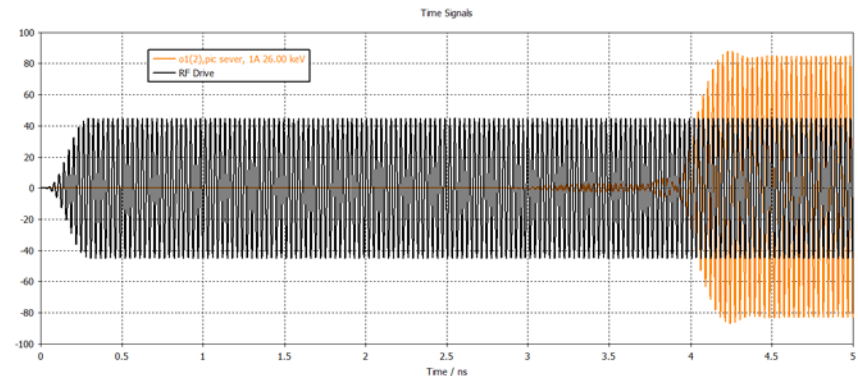


- **Simulation details:**

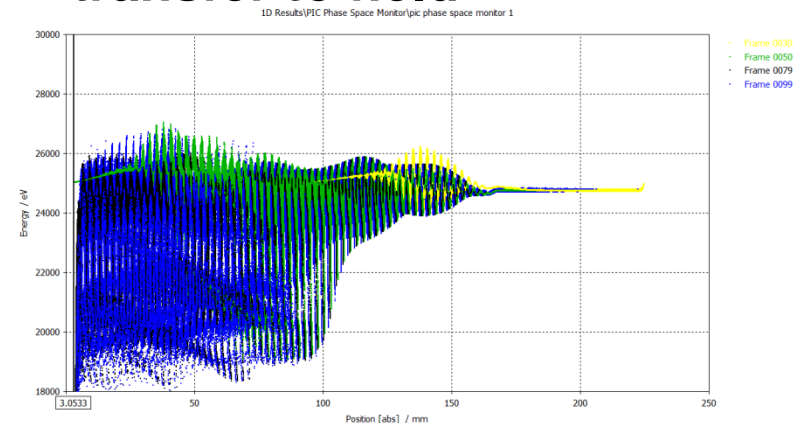
- RF fields need 1 ns to build up – beam start delayed to arrive in structure when RF is at full amplitude



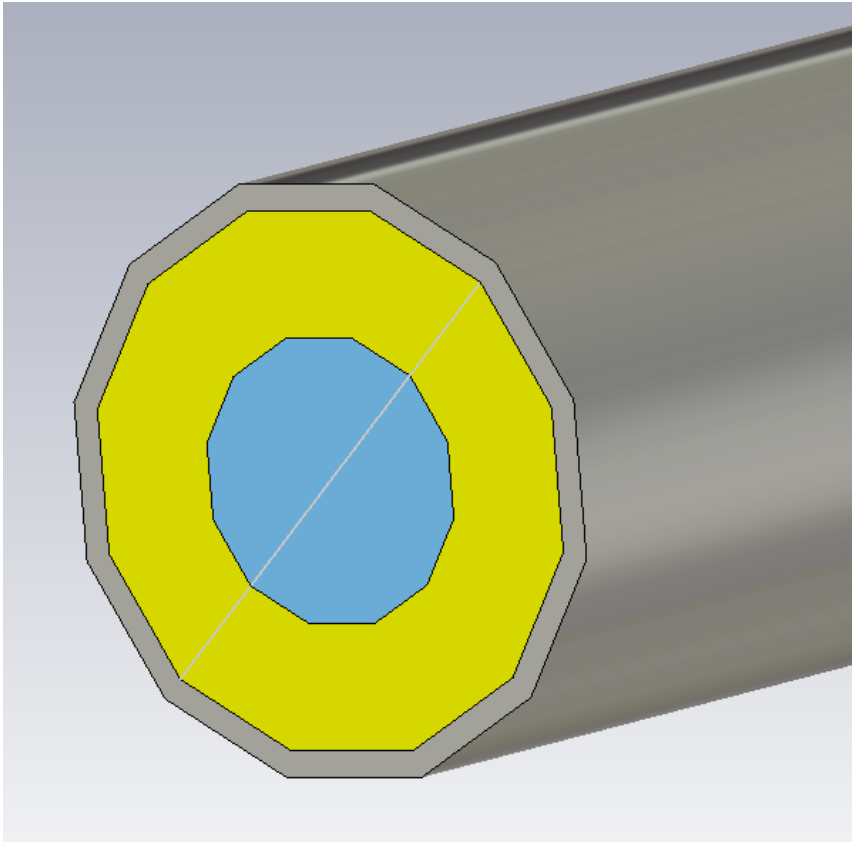
- RF input (black) and output at 26 keV (best gain)



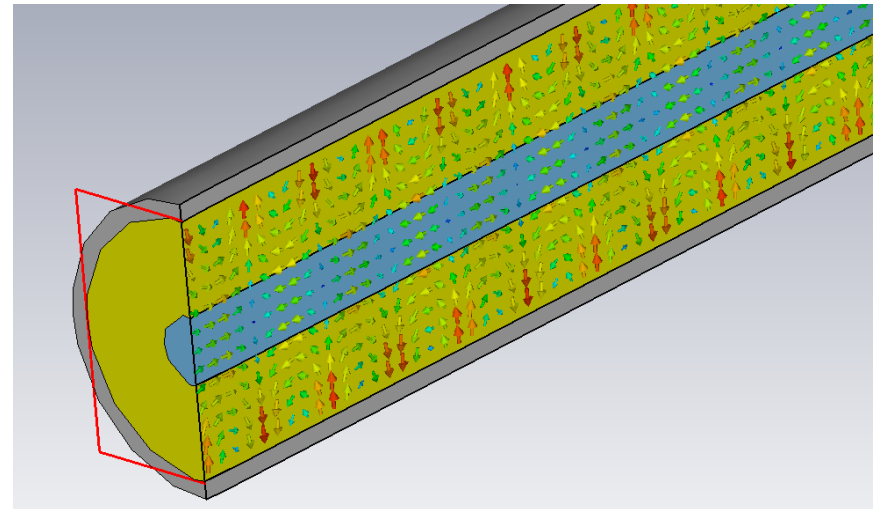
- **Snapshot of energy shows transfer to field**



Simulations of a simpler, circular TWT published by NRL



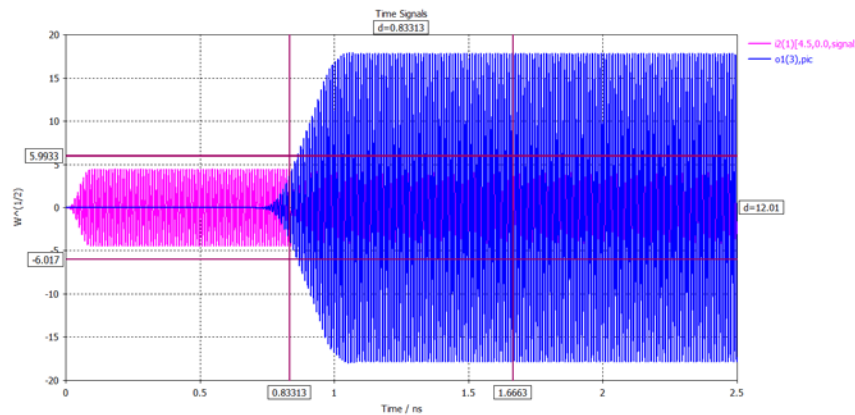
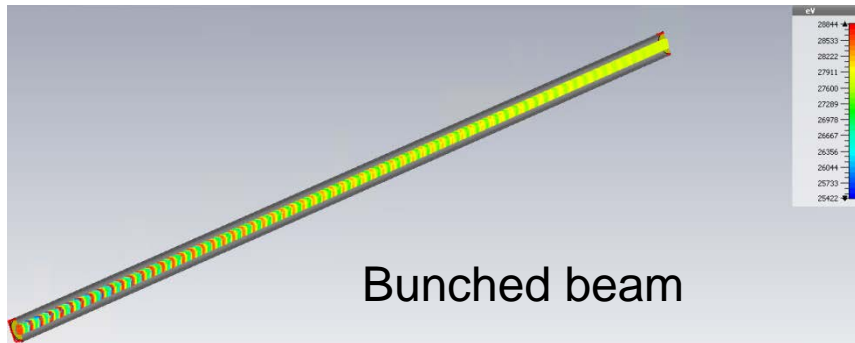
Cross-section for solid beam



Interaction mode without beam

Nominal interaction at 25.75 keV

Simulations of a simpler, circular TWT published by NRL



RF input (pink) and RF output shows gain

Beam energy [keV]	Power in [W]	Power out [W]	Gain [dB]
25.75	20	-	
26.00	20	-	
26.25	20		
26.50	20	23.7	0.74
26.75 (4% high)	20	73	5.6
nominal	10	120	10
27.75 (8% high)	20	306	11.9

Comparison of Typical Parameters

	LANL	NRL	Comments
Frequency	33.25	94	GHz
Energy	20	25.75	keV
Dielectric (ϵ)	20	13.5	
Tan δ	0.001	N/A	Not used
Port modes	15	5	considered
Interaction discrepancy	~25%	~ 5%	

Questions

- **CST cannot find gain in the LANL structure without coupler**
 - Why?
 - ICEPIC result
- **CST finds gain in structure with coupler, but the interaction energy is wrong**
 - Why?
 - ICEPIC result
- **CST does the NRL structure reasonably**
 - Why? Difference to LANL structure?
 - ICEPIC result